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Routing and Reduction of Logistical Costs in the Recyclables' Collection from the Coreso Company

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Abstract

Continuous improvement in companies is always sought in order to improve the functioning and use of resources, as well as the level of services, which together are key factors for decision-making. Thus, highlighting the case proposed by the Coreso company, a study was orchestrated in view of the number vehicles and operators used in the logistics of collecting recyclable waste, as well as the opportunity to optimize travel time, and minimize costs linked to the routes incorporated by the entity. Thus, the solution found to combat these challenges was the routing of the routes used by the vehicles in the company fleet, which was planned and executed in view of the route commonly used and, therefore, there could be an adaptation of a process that had not previously been formalized and regulated, along with visits to strategic points, bypassing the difficulties encountered in the operation of day-to-day activities. In addition, since there was a need for clear and didactic interpretation, a visual and dynamic representation was seen as an alternative that met the requirements, so that the information centralized only to the fleet drivers became easily accessible and adapted to the daily lives of all employees in the best way.

Keywords
Routing, Costs, Transportation, Recyclables.

1. Introduction
In a scenario of growing demand for fast and efficient deliveries and collections, reduced costs, care for the

environment and increased investment in technologies and logistics systems, routing is extremely important within companies. Since the routing process is the planning of routes for more efficient and agile collections and deliveries, combined with cost reduction and the determination of one or more routes or sequences of stops to be made by vehicles in a fleet, there is a tendency to visit a set geographically dispersed points, in predetermined locations, that need to be attended to. However, this system encounters some difficulties throughout the routine, related to the transportation routes and their relationship with the products being transported and collected. According to BALLOU (1993), the routing principle is as important as an essential management activity, and it must help the company to balance its load, bringing benefits through time.

Based on the concepts of logistics routing, this assignment aims to study the logistics needs of the Sorocaba Recycling Cooperative (Coreso), a company that collects recyclables throughout the city of Sorocaba, it goes throughout residences, condominiums, industries and trading, in addition to understanding and getting around the difficulties that the system brings, through proper planning and understanding all the difference that the implementation of efficient routes can have on the company positively, given it does not have this process. It is also necessary to aim for a sustainable application, which covers the three pillars of ESG: Environmental, Social and Governance, as well as dedicating itself to the application of the three UN Sustainable Development Goals, detailed later.

1.1 Objectives

In order to manage the items waiting to be picked up in the best conceivable way, from inputs to finished products, and to promote greater speed and reliability throughout the process, the project uses a cost projection through logistics routing calculations. In addition, its practicality lies in the possibility of a personalized approach that facilitates the integration of the day-to-day work of employees with logistics management systems, providing an even more dynamic development of operations.

In addition, other feasible aspects to be achieved are related to the reduction of labor, and the possibility of identifying a collection pattern throughout the year, helping to plan routes. However, by applying the concepts of Circular Economy, it is possible to offer proposals that would improve the overall process, facilitating employee procedures and proving their implementation through significant data.

Finally, the use of visual and dynamic management comes with functionality of guaranteeing a better combinatorial option for routes, and is an option that meets the need to improve the company's logistics flow, as well as contributing to the decentralization of information on collection points, which would previously have been the sole responsibility of the driver, ensuring that other qualified employees are also able to carry out certain recyclable collection operations.

With regard to the proposal presented, the aim is to optimize the recyclable waste collection route carried out by the Coreso company, focusing on minimizing costs and travel time, so it is possible to study the collection points, the number of trucks available and which ones will be used and the most economical route to be carried out, with the aim of developing and improving routing and flow planning. In addition, the aim is to comply with the concepts of logistics routing, which helps to choose the method that will bring the most efficient results, and based on the general goals, the need to narrow down the targets that will possibly be achieved is considered. In this way, it is intended to analyze the existing route, observing points for improvement and maintenance; integrate logistics routing methods, especially the traveling salesman problem, which uses combinatorial route optimization; minimize idleness in the duration of the journey, studying the best route; propose new collection routes aligned with cost reduction; in addition to achieving three UN Sustainable Development Goals, which are: 9 - Industry, Innovation and Infrastructure, 11 - Sustainable Cities and Communities and Consumption and 12 - Responsible Production.

2. Literature Review

In today's globalized economy, the constant changes and developments in the economic and social environment directly interfere with companies' management processes, especially in relation to technological and media resources, in order to expand their logistics activities (FONSECA, 2018). It is therefore important to identify and deal with bottlenecks in logistics systems, with a focus on routing, which is extremely important for continuous improvement. These processes need to be defined and aligned, ensuring the quality of the delivery or collection carried out in transportation, avoiding problems such as rework and wasted human resources (BALLOU, 2016).

Reducing logistics costs, as well as improving the level of service, are essential elements for the sustainability of companies and decisive factors in decision-making. According to Ballou (2006), transport normally accounts for between one and two thirds of total logistics costs: for reason, increasing efficiency through maximum use of transport equipment and personnel is one of the biggest concerns of the sector. With the need to reduce these costs, several companies have started investing in optimizing their logistics activities by using routing as the main tool for managing logistics costs and improving service (JUNIOR, 2013; NUNES et al., 2013). Nowadays, most delivery and/or collection companies are looking for more effective methods of routing their vehicles, with the aim of making better use of the fleet and drivers, shorter cycle times, shorter collection times and better route planning, thus achieving considerable reductions in operating costs. Vehicle Routing and Scheduling Systems (VRS) are computer systems that can be used to find more viable solutions to routing problems. This method is close to the obstacles of reality, as it considers various physical conditions and restrictions, promoting fast results, making it truly relevant to the process of choosing the most viable route (FILHO, 2002; MELO, 2002).

By applying the routing technique correctly, it is possible to optimize various problems, such as the appropriate number of vehicles, planning viable routes, increasing operational efficiency and fuel consumption, among others (JUNIOR, 2013; NUNES et al., 2013). However, it can be seen that there are still organizations that do not use methods to define transport routes, which can lead to operational inefficiency in logistics transport activities, corroborating the need to apply scientific routing methods, in addition to empiricism and planning experience, in order to improve operational efficiency by choosing the most accessible route, thus being a competitive differentiator for medium and small companies (OLIVEIRA, 2014).

3. Methods

In order to conduct our study on optimizing Coreso's waste collection route, it was necessary to gather the relevant information in order to establish guidelines and an efficient action plan. Initially, an analysis was made of the route previously adopted by the drivers, including streets and neighborhoods served, truck models, travel time and average fuel consumption. With this data in hand, other information was added to develop a new version of the route, ensuring greater precision in the evaluation of the improvements implemented and thus making it possible to examine the limitations of the roads, whether they were one-way or two-way, the gradients of ascents and descents, as well as the certification of the route traveled by the company itself to be benefited. Thus, the basis of the study was structured mainly on the routing of the route and the concept of the "Traveling Salesman Problem", identifying strategic points that would guarantee a more effective mapping for execution. This study was only made possible by a Python program (Figure 1), using mathematical calculations to identify the shortest possible route using the *Branch and Bound* algorithm, which consists of branching the search space and discarding combinations of routes that exceed or do not exceed the optimum solution, avoiding the exploration of unfeasible routes.

```
# Recursive function of the Branch-and-Bound algorithm
def tsp_branch_and_bound(cost_matrix, current_bound, current_weight, level, path, visited, final_path, min_cost):
n= len(cost_matrix)

# Base case: if we've already visited all the cities
if level== n:
# Add the cost of returning to the city of origin
current_weight+= cost_matrix[path[level - 1]][path[0]]

min_cost[0]= current_weight
final_path[:]= path[:]+ [path[0]] # Update the final path
return
```

Figure 1. Python program
Source: Rodrigo Luiz Gigante.

4. Data Collection

Data collection began with conversations and meetings with the company to be benefited, Coreso, so that it would be possible to group the current waste collection routes by days of the week and times of day. Thus, the current grouping of information (Table 1) was as follows:

Table 1. Example of grouping: Tuesday Morning - First Collection.

TUESDAY (MORNING) - I			
DISTRICT	CURRENT ORDER	STREET	NUMBERO F HOUSES
WANEL VILLE (Residential Condominium Jardim Vilaggio Torino)	1	WALTER LACAVA	5
	2	ARMANDO CARMO MANDFREDI	11
	3	DOCTOR JOSÉ DE PAULA NETTO	21
	4	MARIA ALVES SILVA DE PAULA	13
	5	ANTONIO DA SILVA PAULA	14
	6	ANITTA METIDIERI	4
	7	ZILDA MONTEIRO MARTINS	3
	8	RAIMUNDO MENDES BATISTA	4
	9	JOAQUIM GONSALES	8
TOTAL	-	9	83

Source: Coreso.

Using the data provided and collected, it became feasible to create a visual diagram of the current routes for a better understanding of the routes using *Google Maps*, as detailed below (Figures 2, 3, 4, 5 and 6):

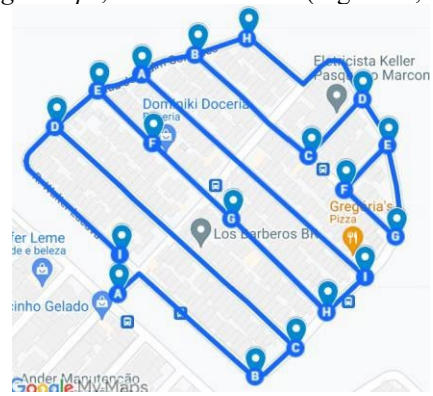

Figure 2. Tuesday Morning: First Collection of the Day.
Source: Prepared by the authors.

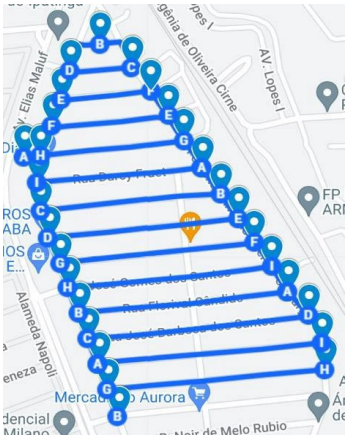

Figure 3. Tuesday Morning: Second Collection of the Day (Source: Prepared by the authors).

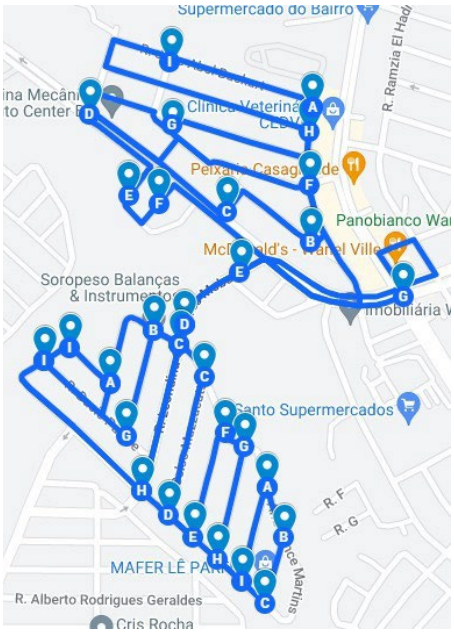

Figure 4. Thursday Morning: First Collection of the Day (Source: Prepared by the authors.)

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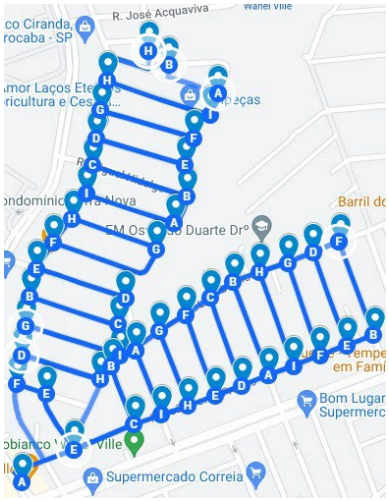

Figure 5. Thursday Afternoon: Second Collection of the Day
Source: Prepared by the authors.

Figure 6. Friday Morning: Only Collection of the Day.
Source: Prepared by the authors.

In addition to studying the routes, it was necessary to understand the model of the vehicle used during collection, in order to better understand the levels of carbon emissions, as well as energy consumption, which is the Volkswagen Delivery 9.160 truck (Figure 7) with an average consumption of 6 Km/L.

Figure 7. Model of the truck used (Source: Monvep Caminhões, 2017).

5. Results and Discussions

5.1 Numerical Results

Through the Python algorithm used, it was possible to obtain some reductions related to the distance and mileage of the route and consequently the reduction time and costs, as separated below (Tables 1, 2, 3, 4 and 5):

A) Tuesday Morning - First Collection of the Day (Table 1): Compared to the current routes, there was a 13% reduction in the time needed to carry out the route after the change in the sequencing of the collection points.

B)

Table 1. Time optimization on Tuesday - 1st collection.

Tuesday Morning - 1st Collection	Current	Proposed	Reduction (%)
Distance (km)	2	2	0%
Time (min)	8	7	13%

Source: Prepared by the authors.

C) Tuesday Morning - Second Collection of the Day (Table 2): Compared to the current routes, there was a 30% reduction in the distance traveled, as well as a 5% reduction in the time taken to complete the route, after the change in the sequencing of the collection points.

D)

Table 2. Time optimization on Tuesday - 2nd Collection.

Tuesday Morning - 2nd Collection	Current	Proposed	Reduction (%)
Distance (km)	7,1	5	30%
Time (min)	19	18	5%

Source: Prepared by the authors.

E) Thursday Morning - First Collection of the Day (Table 3): Compared to the current routes, there was a 4% reduction in the time needed to carry out the route after the change in the sequencing of the collection points.

F)

Table 3. Time optimization on Thursday - 1st collection.

Thursday Morning - 1st Collection	Current	Proposed	Reduction (%)
Distance (km)	7	7	0%
Time (min)	23	22	4%

Source: Prepared by the authors.

G) Thursday Afternoon - Second Collection of the Day (Table 4): Compared to the current routes, there was a 20% reduction in the distance traveled, as well as a 9% reduction in the time needed to complete the route, after the change in the sequencing of the collection points.

H)

Table 4. Time optimization on Thursday - 2nd Collection.

Thursday Afternoon - 2nd Collection	Current	Proposed	Reduction (%)
Distance (km)	10	8	20%
Time (min)	23	21	9%

Source: Prepared by the authors.

I) Friday Morning - Only Collection of the Day (Table 5): Compared to the current routes, there was a 25% reduction in the distance traveled, as well as a 27% reduction in the time needed to carry out the route, after the change in the sequencing of the collection points.

Table 5. Time optimization on Friday (Source: Prepared by the authors).

Friday Morning - Single Collection	Current	Proposed	Reduction (%)
Distance (km)	4	3	25%
Time (min)	11	8	27%

As such, the positive results are clear, as there has in fact been a reduction in the distances traveled by Coreso, as well as the time needed for collection, which generates other benefits, such as the possibility of carrying out other tasks in free time, which until then had been occupied by waste collection. It also brings benefits to the environment, such as a reduction in carbon dioxide emissions, promoting a more sustainable everyday life for everyone around.

5.2 Graphical Results

In addition to the beneficial representation through the percentage saved in minutes, it is extremely important to visualize the proposed improvements graphically, in such a way as to serve as a visual management tool for Coreso. As a result, we were able to obtain an appropriate view of the following proposed routes (Figures 8, 9, 10, 11 and 12):

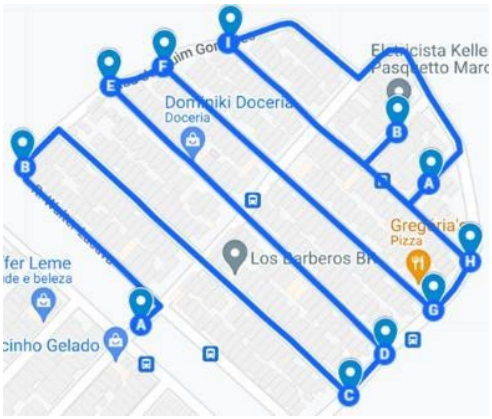

Figure 8. Tuesday Morning - First Collection of the Day (Source: Prepared by the authors).

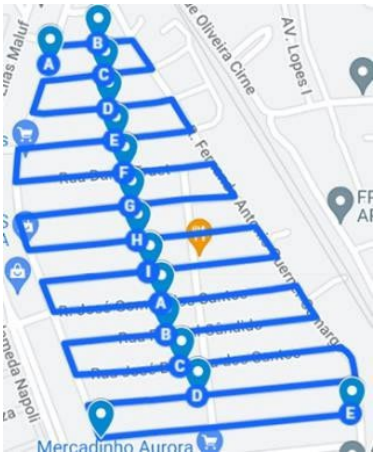

Figure 9. Tuesday Morning - Second Collection of the Day (Source: Prepared by the authors)

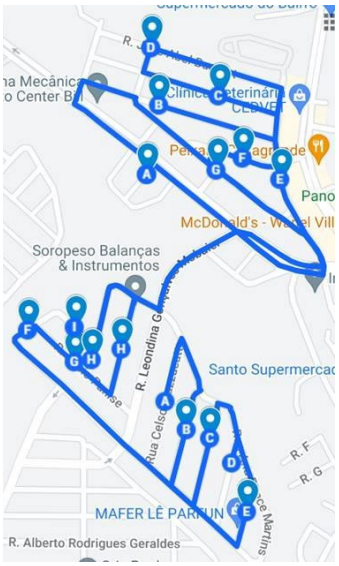

Figure 10. Thursday Morning - First Collection of the Day (Source: Prepared by the authors).

Figure 11. Thursday Afternoon - Second Collection of the Day (Source: Prepared by the authors).

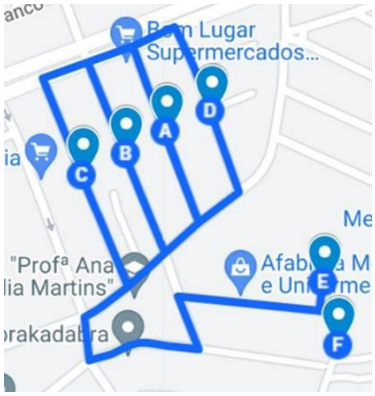

Figure 12. Friday Morning - Only Collection of the Day (Source: Prepared by the authors).

In this way, it was possible to fully visualize the comparison between the current routes and the proposed routes,

with the aim of making employees' day-to-day lives more practical and efficient, so that in the absence of the main driver, any substitute is able to analyze and understand the suggested routes and continue collecting waste as normal. In any case, there is a clear need to provide training and instructions to guide employees to follow the flow correctly, so that there are no failures and misunderstandings in the future, such as the lack of collection at a certain point, for example.

5.3 Proposed Improvements

The general results obtained confirm the range of possibilities for resolving this situation, since this study used the "Traveling Salesman Problem" system, but by applying it to a reality that is more faithful to the work of the employees of the Sorocaba Recycling Cooperative (Coreso), need to install more efficient programs and software that save manual effort, which can be reduced by hiring a company that specializes in transport management and route planning.

On contacting the company *Fusion by NSTECH,* a number of solutions for efficient collection management were offered, including the implementation of software, training, integration with ERP's and even risk management, if necessary. Given that the company benefiting from this study already has a route management consultancy in place, it stands to reason that it would be possible to support the payment of monthly fees and maintenance of the software, or voluntary agreements.

The main point of improvement suggested after the completion of the routing would be the automation of this information, so that if there are any changes to the routes to be taken, or the exclusion of collection points, or even the inclusion of new neighborhoods, it would be feasible for the employees themselves to make these changes through the automated computer solution, making the study even more feasible and making everyday life more practical.

5.4 Validation

As a result, the information provided by the company and the studies conducted using the *"Branch and Bound"* algorithm have resulted in more efficient and dynamic collection points for the company, since they are arranged in the best possible order, systemically. In short, the results themselves make this validation explicit, as there really has been a reduction in routes, both in terms of time, costs, and carbon emissions.

In addition, the application of the routes in Coreso's day-to-day operations has been so successful that it has not been necessary to reallocate the routes to different days, making it possible to maintain the organization already requested and still obtain numerous benefits. Furthermore, for the environment, it is of the utmost importance that these routes continue to work as suggested, as they will reduce the levels of carbon dioxide emissions and their environmental impact. In the economic sphere, the validation comes from the *"saving"* itself, after all, it will no longer be necessary to spend the same amount on fuel as before, in addition to the maintenance carried out on the collection vehicles, which should decrease considerably. In this way, the proposed improvements are realized, guaranteeing greater dynamism and decentralization of competencies that previously belonged only to the driver, as well as the extremely important financial and environmental returns.

6. Conclusion

The implementation of an efficient routing system in the logistics of the Coreso company is a strategic solution to overcome the challenges identified in the logistics management of recyclable waste collections. The study highlights the importance of optimizing routes, offering a greater reduction in costs and travel time, while promoting sustainable practices in line with the ESG sustainability pillars, as well as achieving the UN Sustainable Development Goals.

By analyzing the current and proposed routes, identifying points for improvement and applying optimization methods, such as the traveling salesman problem, it was possible to come up with solutions that meet operational needs and offer greater dynamism to employees' day-to-day activities, decentralizing the role of the driver, who kept the routes in his memory, through experience. Furthermore, decentralizing logistics information and adopting a visual approach that is accessible to all those involved reinforces the effectiveness of the process, increasing reliability and efficiency. The reduction in total time not only adds to the process of collecting recyclables but also improves the quality of life of the drivers, who, by reducing their time on the route, can

allocate their energy to other professional or personal matters.

The monthly reduction of 9.52% between the company's current waste collection routes and the proposed routes stands out, showing a lower logistical cost, a better division of tasks and a lower environmental impact, since the reduction in routes is intended to reduce the emission of high levels of carbon dioxide, thus meeting the UN Sustainable Development Goals mentioned above. It is important to note that these routes are still being validated by the Coreso Company, so it assumes that the theoretical results do show a reduction, which is already being approved.

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Maria Clara da Silva Nogueira is a Production Engineering student at FACENS University, Sorocaba, São Paulo, Brazil. She graduated in logistics from ETEC Fernando Prestes de Sorocaba (2023). She has two projects published in JOINS (Journal of Innovation and Science: research and application), carried out during her studies at FACENS, the first article is related to Decision Support Systems, where the project aims to implement an inventory control system together with a company, with the aim of avoiding waste and delays in deliveries; the second project is related to Safe Mobility, where possible improvements in daily life were discussed, using a smart pedestrian crossing system. She currently works at Companhia Brasileira de Alumínio, in the area of aluminum plate process engineering.

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